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DEPARTMENT OF COMMERCE

UNITED STATES BUREAU OF MINES
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INFORMATION CIRCULAR

SOME NOTES ON METHODS AND COSTS OF EQUIPPING AND DEVELOPING PROSPECTS

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SOME NOTES ON METHODS AND COSTS OF EQUIPPING AND DEVELOPING PROSPECTS[1]

By Chas. F. Jackson[2]

INTRODUCTION

The mining literature is replete with descriptions of methods and costs of operation at producing mines. To day the mine manager can find published information bearing upon almost any problem with which he may be faced. From this literature he can familiarize himself with methods employed by other operators for coping with problems similar to his own, under more or less parallel conditions. Transactions of mining societies, publications of the U. S. Bureau of Mines, technical journals, and handbooks all afford valuable information dealing with operating methods and costs.

Very little has been published, however, regarding methods and costs of equipping and developing new properties and bringing them to the productive stage. There may be some question in the minds of many as to the value of papers on this subject, due to the great variety of conditions encountered. No two prospects are alike. Obviously, it is impossible to forecast what expenditure will be required to develop a mine from a raw prospect or even to predict whether the prospect can be developed into a productive mine.

Each mining district or region, however, generally possesses in common with all properties in that district or region certain features which affect the methods and costs of prospecting, equipment, and development. Thus transportation of men, equipment and supplies, unit costs of drill exploration, shaft sinking and lateral development, constructions of camps and plant buildings, and costs of equipment and supplies are apt to be similar at various properties within a given region.

About 10 years ago the mining methods committee of the American Institute of Mining and Metallurgical Engineers undertook to publish a series of papers on mining methods and costs. The papers obtained appeared in volume 72 of the transactions of the institute. In 1928 the U. S. Bureau of Mines took up this work, and as a result some 100 papers dealing with the subject have been published in the form of information circulars.

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[1] The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from U. S. Bureau of Mines Information Circular 6693."

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Just as no two prospects are alike, no two producing mines are alike. It was realized, however, that by securing data on a large enough number of such mines, covering all conditions, it was not likely that any operator would be faced with conditions to which he would be unable to find a parallel at some other mine, in at least some respects.

It is now suggested that a series of articles dealing with methods and costs of developing and equipping a large number of individual prospects under a wide range of conditions would serve a useful purpose. This paper is published in the hope of encouraging others to undertake the preparation of similar articles on this subject. While as already stated, no amount of data would indicate how much must be spent to make a mine out of a prospect in any individual case, unit costs would serve to indicate how much money must be spent under different conditions to do a certain amount of work -- or conversely, given a certain district and a certain set of conditions, how much development work one should be able to do with a fixed capital sum.

During the early stages of mine development it is the exception rather than the rule that details of costs are kept. This fact may constitute a major reason for the scarcity of published articles on development. However, it is probable that partial costs at a number of properties in a district would, when judiciously pieced together, furnish valuable information.

GENERAL CONSIDERATIONS

Unit costs of development work, shaft sinking, drifting, crosscutting, raising, etc., are usually much higher in a property undergoing development alone than in a producing mine. During the exploratory and development stages, not only are direct labor and supply costs chargeable to the development work, but also all indirect charges, hoisting, pumping, power, surface labor, office expense, insurance, etc., which at a producing property are prorated between development and ore production.

Frequently the development must bear the cost of road or tramway construction, and in remote regions not yet provided with well-organized transport facilities, costs for freighting and hauling of supplies may be excessive. During the early stages of development it may be necessary to sacrifice economy in costs to secure speed of development, and also since the habit of ore occurrence, nature of the ground, etc., have not yet been determined, advantage can not be taken of economies possible in conducting an organized routine of operations such as may be done in an older mine. Furthermore, crews have to be organized, and frequent changes in personnel may be necessary.

All these factors conduce to higher unit costs for sinking, crosscutting, raising, etc., than in a going mine.

During the earlier stages of the development program all other considerations are usually subordinated to the finding and development of ore. Development openings are laid out to facilitate the search for ore. In a producing property the search for additional ore is usually underway, but development is planned with an eye to economic operation, and much attention is given to ways and means to cut production costs, to stoping and support of ground, efficient mine equipment, etc. The development of a prospect is therefore quite a different proposition from the operation of a producing mine.

DATA ON TYPICAL NORTHERN ONTARIO DEVELOPMENT PROJECTS

The last decade or more has witnessed a great deal of activity in the search for and development of lode deposits in Ontario and Quebec. This activity died down for a time but has been revived during the last two years, during which the search has been largely confined to that for gold.

The following discussions and data deal with several typical development projects in this region. Only two of these have as yet reached the productive stage, but each one presents features of interest.

General Characteristics of Region

In general the region may be said to be one of low relief, gently rolling, and with only occasional prominent hills and scarps. It abounds in lakes, streams, and muskeg swamp areas, and bedrock outcrops occupy only a small percentage of the total area. Vast areas are covered with spruce, jack pine, birch, poplar, some white pine, and often with heavy underbrush. Tamarack is plentiful in some of the wetter and more open swamps, and along lake shores stunted cedars are common.

Winters are long and sometimes severe. The snowfall, which is usually considerable, is very heavy in some years and is not uncommon in May and in September. Freeze-up may occur any time from mid-October to late in November and winter roads generally break up some time in April. Summers are generally quite cool, but occasional very hot spells of short duration may occur during late June, in July, or early in August. There is apt to be a dry spell following the disappearance of the snow in the spring and before fresh green vegetation appears, during which bush fires may be prevalent. Black flies and mosquitoes are annoying during the summer months and add to the difficulties of working in the Canadian "bush."

Transport of Men, Equipment, and Supplies

No serious transport problems are presented at properties near the larger camps which are provided with roads and railroad facilities. Transportation often is a major problem at properties remote from the railroad, however, and the taking in of men, equipment, and supplies may constitute an important item of cost.

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Water transportation has in some cases been feasible and economical where waterways are deep and wide enough to float craft capable of carrying heavy and bulky equipment and where little portaging is necessary. Often, however, only canoes can be used or there are so many portages that repeated transfer of material makes the cost of water freighting prohibitive.

The solution in a number of cases, and in those upon which this paper is based, has been to transport heavy equipment, supplies, and nonperishable foodstuffs on sleds over winter roads and to use airplanes for handling men, perishable foodstuffs (in the summer) and emergency supplies. There is usually water upon which planes can be landed in summer (on ice in winter) within a short distance of the properties. There is about a month during the fall freeze-up and another month during the spring break-up when neither water nor ice landings can be made and the use of airplanes must be suspended temporarily.

Central Patricia mine[3].- The Central Patricia mine is about 100 miles north of Savant Lake, a station on the Canadian National Railway. It can be reached by canoe from Hudson in from five to eight days, ten portages being necessary. The water trip is arduous, so that all heavy transportation was by tractor trains over winter roads, while men and some supplies were taken in by plane. The tractor route was 120 miles long and some clearing was required for winter hauling. The first tractor train left Savant Lake on January 12, 1930, carrying only a light load; the trip was made chiefly for the purpose of breaking the road. Approximately 400 tons of machinery and supplies were transported in five round trips of 12 days each, the average load being 80 tons per trip. Seven tractors were rented from Winnipeg, 24 sleighs and a snow plow were purchased, and two cabooses were constructed to serve for traveling cookhouse and commissary purposes.

The first men of the transport crew arrived at Savant Lake on November 10, 1930, and the last man left April 10, 1931, having completed the transportation job. The crew consisted of 1 yard foreman, 1 loader, 1 clerk, 1 train foreman, 1 cook, 1 night watchman, 1 woodcutter, 1 train cook, 6 drivers (3¼ months), 2 drivers (4 months), and 5 drivers (3 months). The cost of transportation is summarized as follows:

Labor and board	$13,214.00
Return fares of crew and manager of freighting company	497.00
Rent of buildings, building material, tents	750.00
Twenty-four sleighs at $165 each, cabooses, material for sleigh racks	4,310.00
Gasoline, oil, and antifreeze	2,950.00
Repairs and incidentals	1,200.00
Snowplow	3,000.00
Rental and freight on tractors	8,043.00
Total	33,964.00

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[3] Keast, A. J., and Jackson, Chas. F., Method and Cost of Exploring, Equipping for Development, and Developing the Central Patricia Group of Claims, Northern Ontario: Inf. Circ. 6681, U. S. Bureau of Mines, 1933, 13 pp.

Unit costs were therefore about $85 per ton of freight hauled, or 71 cents per ton-mile inbound. At present costs have come down to such an extent that freighting to the mine can be contracted at $50 to $60 per ton.

The air trip is about 100 miles long, landings being made on a lake 3 miles from the mine. The airplanes which have proved most satisfactory carry about 1,500 pounds, and supplies can now be flown in for about 4½ cents per pound, though previously they were much higher. In 1931 the regular round-trip passenger rate was $85, but by guaranteeing a certain minimum amount of business, considerably lower rates were obtained.

Ashley Mine.- The Ashley mine is about 32 miles in a straight line from rail head at Elk Lake and 42 miles by winter road. The discovery was made in October, 1930. During the following winter about 700 tons of freight were taken in over winter roads; the next season 1,457 tons were hauled.

During the first winter, hauling from Elk Lake was by horse-drawn sleds carrying an average load of 5,500 pounds. One tractor was also employed between Elk Lake and Moyneurs, 25 miles from Elk Lake. This tractor pulled two or three sleds with an average total load of 10 tons. During the second winter five tractors were used between Elk Lake and Moyneurs, while teams were employed from Moyneurs to the mine. When hauling from Elk Lake to the mine by team, five days were required for a round trip. The tractors worked continuously, making 4 miles per hour when the road was in good condition.

All hauling was done on either a cost-plus or on a contract basis. The contract price was $45 per ton during the first season and $27 per ton the second. In the first season, winter hauling did not start until February, and as the remaining season was short, speed rather than price was the primary consideration. Railway freight on material handled the second season was $9,109 or $6.25 per ton, and the hauling cost was $38,299 or $26.28 per ton, equivalent to 62½ cents per ton-mile.

Airplane service from Elk Lake was begun immediately after the discovery of the property in October, 1930, and has been in continuous service ever since, except during the autumn freeze-up and spring break-up. A 4-seated, Bellanca plane equipped with pontoons in summer and skis in winter is employed, which carries a maximum pay load of 1,150 pounds. Landings are made on Elk Lake and on Ashley Lake, 3 miles from the mine. Ordinary cruising speed is 100 miles per hour and the trip from landing to landing requires about 20 minutes. In 1932 the minimum rate for passengers was $25 per one-way trip or $10 per passenger if there were three or more passengers. During 1931 when men were traveling back and forth and the plane was making daily trips, $10 per passenger was charged, with no minimum trip rate. Freight, including baggage, is taken at 6 cents per pound, equivalent to about $3.75 per inbound ton-mile. During 1931 about 45 tons of freight were taken in by plane and $2,829 was paid for carrying passengers to and from the mine.

Bobjo Mine.- The Bobjo property is in the Patricia district, 120 miles from a railroad. Work was started by the company in September, 1928. Men and perishable foodstuffs were transported by plane. Heavy supplies were hauled by tractors and teams in the winter over ice and snow roads. In summer, supplies can be taken in by water and teaming over portages, there being approximately 20 miles of portages.

Winter transportation by tractor cost 7 cents per pound or $140 per ton. Airplane transport of perishable foodstuffs cost 12 cents per pound under contract. Airplane transport of men cost $36 each per trip.

Other Properties.- At another property 14 miles from the railroad, 11 miles of which was rough corduroy, summer hauling was contracted for at $25 per ton. In another instance where a 27-mile water route with one short portage reached to within a mile of the property, freight was handled for about $7 to $8 per ton. The lake 1 mile from this property can be reached by airplane from another railroad point in about 15 to 20 minutes.

Camp and Plant Buildings and Equipment

The expenditure for camp and plant buildings will vary with the magnitude of the operations, size of the crew, and whether the property is close to a railroad or remote therefrom. Timber can usually be cut and sawed locally in the more remote camps, and firewood is plentiful. The following examples are probably more or less typical of the region.

Central Patricia Mine.- Buildings at the Central Patricia mine were constructed of lumber cut and sawed on the property. The camp accommodated 60 men. Camp buildings consisted of four bunk houses 16 by 18 feet to 20 by 32 feet in plan, a cookery 50 by 24 feet, a house 24 by 24 feet, two storehouses 20 by 40 feet and 18 by 24 feet, respectively, a meat house 24 by 30 feet, an ice house 12 by 14 feet, and two small root houses. These buildings cost $6,559. Camp equipment such as beds and bedding, stoves, kitchen utensils, and tableware cost $2,287.

Plant buildings were as follows: Blacksmith shop, 20 by 28 feet; power house and hoist room, 28 by 80 feet; dry house, 18 by 28 feet; assay office, 16 by 28 feet; office and storehouse, 24 by 28 feet; powder magazine, 18 by 20 feet; thaw house, 8 by 10 feet; cap and fuse house, 8 by 10 feet; pump house, 8 by 10 feet; 10,000-gallon water tank; stable, 10 by 10 feet; old drafting office, 6 by 18 feet; tractor house, 10 by 16 feet; and a timber headframe. These buildings were erected at a cost of $9,084, including freight and haulage to the mine.

Plant equipment cost $60,847, including freight and hauling, and machinery foundations. The principal items were blacksmith and steel sharpening equipment, $2,986; powerhouse tools, $5,616; hoist and foundations, $6,705; compressor and foundations, $13,315; boilers and foundations, $15,015; saw mill,

mill, $2,228; assay office, $1,641; diamond drill, $4,949; 30-hp. caterpillar tractor, $4,337. Underground equipment, including four $3\frac{1}{2}$-inch Leyner-type rock drills, 7 tons of drill steel, pumps, ten 1-ton mine cars, sinking buckets, etc., cost $11,077.

Total cost of camp and plant buildings, surface plant equipment, and underground equipment was $89,854.

Ashley Mine.- A small temporary camp was first built at the Ashley mine to house the trenching and diamond-drilling crews, and consisted of the following log buildings: Office, 20 by 30 feet; blacksmith shop, 14 by 16 feet; combined cookery and bunk house for eight men, 20 by 30 feet; and a stable for 3 teams. These buildings cost $1,134 to erect. A second 24 by 42 foot log bunk house was started on December 10, 1930, and was ready for occupancy on December 19. It cost $1,294. Cookery stores, freight and teaming, miscellaneous pay roll, travel expense, etc., amounted to $9,195 during the first three months.

The scale of operations was expanded rapidly at this property and many new structures were required during the first 18 months and previous to the construction of the 150-ton mill which was completed in August, 1932. By this time there were 35 camp and plant structures, a few tents, a steel headframe, steel water tank and standpipe, and a substation on the property.

Several of the earlier buildings were constructed of logs with frame roofs, and most of the other buildings were of frame covered on the outside with asbestos-base roll-siding and roofing. Building paper or other insulating lining was used between all double floors and 2-ply frame walls and roofs. The main office, assay office, dining room, cookery, bunk house, and hospital were ceiled inside with insulating board, and electric lighting was installed in all the principal buildings.

On July 15, 1932, the cost of all camp and plant buildings and structures, including five buildings and a wooden water tank which had been torn down, stood at $62,870. Costs include stumpage at $14.50 per thousand, cutting and sawing, hauling, and erection. The largest items of cost were as follows: Main office, 20 by 14 by 18 foot wall, $1,475; main storehouse and time office, 24 by 24 by 21 feet, $1,700; mine supply storehouse, 24 by 36 by 14 feet, $1,075; cookery and dining room, 53 by $29\frac{1}{2}$ by 24 feet, $3,419; two bunk houses (2-story) each 48 by 24 by 28 feet, $8,532; hospital cottage, 24 by 28 by 17 feet, $1,352; dry house, 16 by 52 by $8\frac{1}{2}$ feet, $1,028; 2,700-foot pipe line, $2,122; machine and carpenter shops, 24 by 72 by $10\frac{1}{2}$ foot wall, $2,417; compressor and hoist house, 60 by 32 by $10\frac{1}{2}$ foot wall, $5,602; steel water tank, $5,682; and steel headframe, $9,355.

The cost of camp and plant equipment and stores on the same date, July 15, 1932, stood at $128,528, including freight, hauling, and installation. The largest items were as follows: Main office, $1,558; assay office, $2;925; main storehouse and time office stores and equipment, $6,800; mine supply storehouse, $4,500; cookery and dining room, $2,463; cookery stores, $9,000; bunk-house equipment, $3,594; hay, $1,388; blacksmith shop, $2,756; pump house at creek, $3,150; explosives, $17,500; pumps and motors stored in motor shed, $10,397; machine and carpenter shop, $7,257; electric shop, $1,100; steam power plant, $19,000; compressor and hoist, $24,306 (hoist and compressors are electrically driven); sawmill transmission line, $2,750.

Other Properties.- At the Bobjo property camps were erected to accommodate a maximum of 35 men. Camp and mine buildings were constructed of logs with board roofs covered with 3-ply roofing paper. There were two bunk houses, a cookery, and a combined office and living quarters for the superintendent. Plant housing consisted of a blacksmith shop, boiler house, compressor and hoist house, and a wooden headframe. Camp buildings and housing of plant cost $12,760. Camp and mine equipment cost $36,276, the principal items being a drill sharpener; two 70-hp. locomotive-type boilers; a steam-driven, 500-cubic foot compressor; sinking buckets, cage, and mine cars; an 8 by 12 steam hoist; and small water supply and mine pumps. Inventory of mine equipment, tools and supplies at the time property was closed down was $19,621.

At the Macassa mine it was unnecessary to construct camps because of proximity of the property to the town of Kirkland Lake. Ten buildings were required to house the mine plant, however, as follows: Office, 20 by 20 feet; hoist and compressor house, 30 by 50 feet; dry house, 19 by 25 feet; boiler house (for heating only), 25 by 17 feet; blacksmith shop, 17 by 22 feet; topman's house, 17 by 22 feet; pump house, 18 by 18 feet; substation, 12 by 12 feet; powder magazine, 14 by 16 feet; and cap house. These were frame buildings costing $5,854. Surface plant and equipment cost $50,810. The largest items were: Electric hoist (for sinking to 2,500 feet) installed complete, $26,823; headframe, $2,938; 1,000-foot electrically driven compressor installed complete, $8,494; blacksmith shop and steel sharpener, $2,462; and substation equipment, $6,528. Mine equipment including rock drills, drill steel, pumps, mine cars, etc., cost $7,267. The total preliminary expenditure is summarized as follows:[4]

Mine road and clearing site	$ 2,297
Buildings	5,854
Plant equipment, including headframe	50,810
Mine equipment	7,267
Total	66,228

Preliminary Exploration

The first exploratory work consists of trenching and shallow test-pitting. If the results of this work are encouraging, diamond drilling usually follows, prior to embarking on exploration by underground methods.

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[4] Howes, G. A., and Jackson, Chas. F., Shaft Sinking Methods and Costs, and Cost of Plant and Equipment at the Macassa Mine, Kirkland Lake, Ontario: Inf. Circ. 6674, Bureau of Mines, 1932, 10 pp.

Conditions vary widely at different properties and the amount of trenching required and the cost thereof vary accordingly. During this period costs are usually lumped, and seldom, if ever, is an accurate record kept of the cubic yards of material excavated.

At the Central Patricia the average depth of overburden removed in trenching was 5 feet, and a rough estimate shows that about 1,050 linear feet of trenching was done. Diamond-drill exploration comprised 30 holes, totaling 6,000 feet in length. The drilling was done on contract, log camps being built at the expense of the contractor for housing the crew. The cost of preliminary exploration, location and surveying of 18 claims, trenching, and 6,000 feet of diamond drilling was $60,280.

At the Ashley mine the discovery was made on the side of a low ridge where the vein outcropped and showed visible gold and sulphides. Four short trenches within a distance of 150 feet along the strike disclosed the vein which exhibited good values. The vein then passed under a muskeg swamp and could not be prospected further by trenching. More trenching was done later, but after digging about 150 linear feet of trenches, it was decided to bring in two diamond-drill outfits.

Drilling started on December 24, 1930, and by January 7, 1931, four shallow holes had been completed totaling 359 feet of drilling. Much difficulty was experienced in these and later holes in getting to bedrock. Furthermore, the rock was badly seamed and fractured, carbon loss was exceptionally high, and some holes had to be cemented. Six more holes, varying in depth from 139 to 291 feet and comprising 1,314 feet of drilling, were completed by February 27, 1931. Four holes, totaling 474 feet in length, were then drilled on adjoining claims and two more on the Ashley claims. The first 16 holes were drilled on a cost-plus basis, and because of the difficulties encountered and the high carbon loss, they were expensive. Three holes drilled later, the deepest of which was 750 feet, were drilled at a base contract price of $4.15 per foot for drilling, with extra charges for cementing, etc. The company furnished fuel for drilling all the holes. Following is a summary of the cost, exclusive of fuel and teaming:

Holes	Feet drilled	Total cost	Cost per foot
1 to 16	2,743	$20,047.92	$7.31
17 to 19	2,044	9,320.64	4.56
Total and average	4,787	29,368.56	6.14

At the Bobjo property about $6,000 was spent in trenching, test pitting, and geological mapping. Records were not kept of the yardage excavated in trenching and test-pitting. The cost of preliminary exploration and diamond drilling is summarized as follows:

Trenching, test pitting, exploration	$ 5,027
2,000 feet of drilling at $5 contract price ...	10,000
Supervision and incidentals	525
	15,552

At another property, 14 miles from railhead, 2,000 feet of drilling was done from surface at a cost of $3.45 per foot plus fuel and local teaming, as follows:

	Cost per foot
Contract price	$3.216
Pipe and pipe fitting	.001
Sampling and assaying	.028
Proportion of general charges	.202
Total	3.447

Drilling can sometimes be contracted at a price per foot plus a share interest in the property. In such instances a price is set which the contractor estimates will cover his bare costs. Certain provisions are usually made for additional payment for delays not under control of the contractor. In the instance of one property situated about 30 miles from the railroad, the first contract covered a minimum of 2,500 feet of drilling at $3.50 plus two shares of stock per foot if a company should be formed. The second contract called for 3,000 feet more of drilling at $2.50 plus 2 shares of stock per foot. The third contract was at a price of $2.50 for holes from 0 to 1,200 feet deep, with an increase of 25 cents per foot for every additional 1,000 feet; one share of stock per foot of hole was added to these prices.

Underground Exploration and Development

Shaft Sinking.- Following are the costs of shaft sinking at several properties in Ontario.

Property No. 1.- Property No. 1 is 120 miles from the railroad by winter road. The vertical shaft, 6½ by 16 feet outside the 8 by 8 inch sawed timbers, was sunk by hand to a depth of 30 feet prior to installation of boiler plant and hoist. The shaft has two 4½ by 5 foot hoisting compartments and a manway and pipe compartment. Shaft stations were cut at 125-foot intervals as the shaft reached these horizons. The total depth is 527 feet. Detailed costs were as follows:

Detail of costs per foot of shaft, property No. 1

Labor, direct:	
Machinemen and helpers	$ 9.542
Muckers	14.016
Total direct underground labor	23.558

Detail of costs per foot of shaft, property No. 1 - Continued

Supplies and maintenance:	
Explosives	$ 7.546
Timber and timbering	9.471
Drill maintenance	.312
Steel and steel sharpening	2.680
Pipes and pipe fitting	4.634
Miscellaneous supplies	.314
Total supplies and maintenance	24.957
Other costs:	
Hoisting	4.871
Landing and dumping	2.794
Compressed air	5.315
Pumping	3.249
Lighting	.144
Handling explosives	.051
Operation of mine dry	.099
Repairs to mine tools	.144
Cars and track maintenance	.120
Shaft repairs	.035
Total, other costs	16.822
Total, all direct charges	65.338
Proportion of general charges	13.026
Total cost per foot of shaft	78.364

Four shaft stations, aggregating 89.3 feet in length, cost $6,084, or $68.13 per foot.

Property No. 2.- Property No. 2 is 42 miles from railhead by winter road. The shaft was sunk to a depth of 585 feet in several different stages, between each of which the work was stopped in the shaft while lateral development was being done. Intermittent working contributed to somewhat higher costs than would otherwise have been the case. The shaft is inclined on a slope of 53° from the horizontal, is 17 feet 6 inches by 6 feet 2 inches outside the sets of 7 by 7 inch framed timber, and is divided into three compartments -- two for hoisting and the other for manway, pipes, and power cables.

The costs of sinking the first 68 feet of the shaft were not segregated. Costs of sinking from 68 feet to 504 feet or a total distance of 436 feet measured on the incline, are summarized as follows:

Costs per foot of shaft

Direct shaft labor:	
Wages of shaftmen	$ 34.00
Bonus to shaftmen	10.19
Total direct shaft labor	44.19
Explosives	5.46
Materials and supplies (prorated):	
Cost of rock drills, hose, bars, fittings and parts	4.09
Drill steel	1.20
Pipe and fittings	4.09
Timber and timber framing	13.15
Shaft rails	2.45
Boiler fuel	9.55
Gasoline, oil, and grease	3.40
Total prorated materials and supplies	37.93
Prorated labor:	
Blacksmithing, steel sharpening, and drill repairs	3.41
Decking and surface tramming	3.17
Hoisting and air compression, including labor hauling boiler fuel	11.28
General teaming	2.08
General underground labor	4.15
General surface labor	1.65
Total prorated labor	25.74
Salaries, office, and medical expense (prorated).	5.77
Total cost per foot of shaft	119.09

Property No. 3.- Property No. 3 is remote from the railroad. The shaft is a vertical 2-compartment shaft, 6½ by 12 feet in cross section, timbered with 8 by 8 inch framed sets. It was sunk to a depth of 268 feet in 1929 and stations were cut at the 125 and 250 foot levels. The sinking labor and explosives were contracted for at $55 per foot, and the total cost of the shaft exclusive of stations was about $87 per foot, including supplies, overhead, and cost of the small sinking headframe.

Property No. 4.- Property No. 4 is close to the railroad and power lines. Electrically-driven equipment was used in sinking the vertical shaft, which has rock dimensions of 9 by 17 feet, is timbered with 8 by 8 inch sets on 7-foot centers, and has three compartments. Shaft sinking was started in May, 1931, and was completed on August 9, 1932, at a depth of 2,489 feet. The sinking cost was $70.93 per foot, as tabulated below. The costs include the purchase price of a number of items of equipment such as drill steel, sinking buckets, hoisting cable, etc., as well as all overhead charges.

Shaft-sinking costs per foot (2,489 feet), property No. 4

	Shaft labor and supervision	Drills, drill repairs, steel, air and water lines	Electric power	Explosives	Timber	Concrete collar	Miscellaneous supplies	Totals
Drilling and blasting	$10.378	$3.564 (mat'l) 3.062 (labor)	$2.899	$6.367	-	-	$0.218	$26.488
Mucking	10.884	-	-	-	-	-	.166	11.050
Timbering	3.546	-	-	-	$6.087	-	-	9.633
Concreting ...	-	-	-	-	-	$0.215	-	.215
Hoisting	2.987	-	2.971	-	-	-	2.224	8.182
Decking and rock disposal	3.570	-	-	-	-	-	.033	3.603
Ventilation ..	-	1.519	.050	-	-	-	-	1.569
Pumping	-	-	.536	-	-	-	1.698	2.234
Supervision, and workmen's compensation.	4.810	-	-	-	-	-	-	4.810
Miscellaneous.	-	-	.125	-	-	-	.509	.634
Total direct cost	36.175	8.145	6.581	6.367	6.087	0.215	4.848	68.418
Proportion of general charges								2.512
Total cost per foot sunk								70.930

Property No. 5.- Property No. 5 is remote from rail transportation. The 3-compartment, vertical shaft, 6 by 16 feet in cross section, was sunk to a depth of 556 feet. Costs per foot are summarized as follows:

Summarized costs per foot of shaft, property No. 5

Shaft labor:	
Drilling and blasting, timbering and decking	$ 29.448
Timber framing and pipe fitting	.815
Total shaft labor	~~30.663~~ 30.263
Materials, supplies, and repairs:	
Explosives	5.380
Timber	5.057
Drill repairs	1.211
Steel and steel sharpening	2.107
Pipes	1.822
Miscellaneous	.073
Total materials, supplies, and repairs	15.650
Other costs:	
Hoisting, landing, and dumping	6.523
Compressed air	3.297
Pumping	1.599
Miscellaneous	.525
Total other costs	11.944
Total direct costs	57.857
Proportion of general charges	10.639
Total cost per foot of shaft	68.496

Property No. 6.- Property No. 6 is 2½ miles from the railroad by improved road. The shaft is 14 feet 9 inches by 6 feet 8 inches outside the timbers and was sunk to a depth of 475 feet in 1928. Costs per foot of shaft ~~were as~~ follows:

Costs per foot of shaft, property No. 6

Direct shaft labor:	
Sinking and timbering	$28.936
Timber framing and pipe fitting	1.925
Deckmen	2.646
Total direct shaft labor	33.507

Costs per foot of shaft, property No. 6 - Continued

Supplies and maintenance:	
Explosives	$ 5.164
Timber	6.947
Drill repairs	.634
Steel and steel sharpening	1.999
Pipes	.782
Miscellaneous	1.340
Total supplies and maintenance	16.866
Other costs:	
Hoisting, landing, and dumping	3.928
Compressed air	2.898
Pumping	.112
Miscellaneous	.246
Total other costs	7.184
Total direct costs	57.557
Proportion of general charges	8.143
Total cost per foot of shaft	65.700

Lateral Development

Property No. 1.- The lateral development at this property consisted of 1,775.7 feet of drifting and 1,019.3 feet of crosscutting. The costs per foot of development are itemized below.

Costs per foot of drifting and crosscutting, property No. 1

Labor, direct:	Drifting	Crosscutting
Machinemen and helpers	$ 3.378	$ 3.536
Shovelers	2.832	3.031
Total direct labor	6.210	6.567
Supplies and maintenance:		
Explosives	3.498	3.543
Timbering	-	.018
Drill maintenance	.382	.449
Cars, track and maintenance	.373	.635
Steel and steel sharpening	1.262	1.387
Pipes and pipe fitting	.952	.654
Miscellaneous supplies and repairs	.177	.159
Shaft repairs	.034	.067
Total supplies and maintenance	6.678	6.912

Costs per foot of drifting and crosscutting, property No. 1 - Continued

Other costs:	Drifting	Crosscutting
Hoisting	$ 1.142	$ 1.420
Landing and dumping	.820	1.030
Compressed air	1.765	2.025
Sampling and assaying	.451	.433
Pumping	.800	1.210
Mine lighting	.134	.134
Handling explosives	.017	.047
Operation of mine dry	.021	.030
Repairs to mine tools	.007	.017
Total other costs	5.157	6.346
Total direct costs per foot	18.045	19.825
Proportion of general charges	3.181	4.263
Total per foot	21.226	24.088

Property No. 2.- Costs per foot of drifting and crosscutting, raising, and cutting shaft stations and pockets at property No. 2 are tabulated as follows:

Costs per foot of drifting and crosscutting, property No. 2

	Drifts, crosscuts, and slashes 4,308 feet	Raises 638 feet	Stations and pockets 230 feet
Direct labor, drillers, shovelers, and trammers	$ 6.24	$ 6.79	$21.23
Explosives	2.91	3.68	3.08
Total direct charges	9.15	10.47	24.31
Materials and supplies (prorated):			
Rock drills, accessories, and drill parts.	1.70	1.94	4.79
Drill steel	.60	.68	1.68
Pipe and fittings	1.03	1.16	2.87
Track and fittings	1.05	-	-
Boiler fuel and power	2.09	2.42	5.68
Oils, gasoline, and grease	.75	.84	2.08
Total prorated materials and supplies	7.22	7.04	17.10

Costs per foot of drifting and crosscutting, property No. 2 - Continued

	Drifts, crosscuts, and slashes 4,308 feet	Raises 638 feet	Stations and pockets 230 feet
Prorated labor:			
Blacksmith and steel sharpening	$ 0.69	$ 1.12	$ 2.75
Decking and surface tramming	.60	.67	1.66
Hoisting and air compression, including hauling boiler fuel	2.12	2.39	5.90
General teaming around plant	.39	.44	1.08
General underground labor	.97	.88	2.17
General surface and camp costs	.31	.35	.86
Total prorated labor	5.08	5.85	14.42
Total except salaries, office, and medical	21.45	23.36	55.83
Salaries, office, and medical expense	1.09	1.22	3.02
Total cost per foot	22.54	24.58	58.85

Property No. 3.- A total of 1,786 feet of crosscutting and drifting was done at a cost of $37,667; the per-foot cost was therefore $21.09. During the course of drifting $10,474 was recovered from high-grade ore removed, making the net cost $15.23 per foot.

Property No. 5.- The cost per foot of 2,579 feet of drifts and crosscuts at property No. 5 is tabulated as follows:

Cost per foot of drifting and crosscutting, property No. 5

Direct labor:	
Machinemen	$ 2.955
Shovelers	2.490
Total direct labor	5.445
Supplies and maintenance:	
Explosives	3.417
Drill maintenance	.447
Cars and track	.150
Steel and steel sharpening	.942
Pipes and pipe fitting	.319
Repairs to shaft	.024
Miscellaneous	.064
Repairs to mine tools	.008
Total supplies and maintenance	5.371

Cost per foot of drifting and crosscutting, property No. 5 - Continued

Other costs:	
Hoisting	$ 2.026
Landing and dumping	.872
Compressed air	1.436
Sampling and assaying	.485
Pumping	.323
Lighting	.068
Handling explosives	.004
Mine dry	.124
Total other costs	5.338
Total direct charges	16.154
Proportion of general charges	3.248
Total cost per foot	19.402

Property No. 6.- Drifts and crosscuts on property No. 6 aggregated 6,956 feet in length; the costs per foot were as follows:

Costs per foot of drifts and crosscuts, property No. 6

Direct labor:	
Machinemen and helpers	$ 4.270
Shovelers	1.506
Total direct labor	5.776
Supplies and maintenance:	
Explosives	2.486
Drill maintenance	.318
Steel and steel sharpening	.716
Pipes and pipe fitting	.243
Cars and track	.210
Shaft repairs	.001
Miscellaneous supplies and repairs	.068
Mine tools	.007
Total supplies and maintenance	4.049
Other costs:	
Compressed air	1.493
Hoisting, decking, and dumping	2.204
Sampling and assaying	.129
Pumping	.186
Lighting	.046
Handling explosives	.022
Dry operation	.051
Total other costs	4.131
Total direct costs	13.956
Proportion of general charges	2.954
Total cost per foot	16.910

The raising cost was $18.88 per foot, including $2.75 of the general charges.

Summaries of Expenditures

Property No. 1.- At property No. 1, 120 miles by winter road from railhead, development was carried to a depth of 500 feet, disclosing ore amounting to 33,155 tons of an estimated average value of $13.71 per ton in gold, or a gross value of $454,555, and "possible ore" amounting to 12,000 tons of an estimated average value of $12 per ton in gold. At this point operations were suspended for a time. The expenditures are summarized as follows:

Summary of expenditures, property No. 1

Preliminary exploration; staking, surveying, trenching and 6,000 feet of diamond drilling	$ 60,280.00
Cutting winter roads and clearing land	7,057.00
Buildings, plant, and equipment	89,854.00
Shaft, 527 feet deep	41,321.00
Four shaft stations and pump sump	6,827.00
Drifting, 1,776 feet	37,691.00
Crosscuts, 1,019 feet	24,553.00
Surface exploration	172.00
Cost of shutting down, pulling pumps, etc................	1,360.00
Total	269,115.00

In addition to the above, $60,325 had been expended for stores and supplies not used up.

Property No. 2.- Property No. 2 is 42 miles by winter road from railhead. Discovery was made in October, 1930, and the property had been partly developed to a depth of 504 feet (inclined distance), a mill was erected, and productive operations were started late in August, 1932. Expenditures are summarized as follows:

Summary of expenditures, property No. 2

Expense during first 3 months, exclusive of drilling	$ 10,987
Diamond drilling	29,369
Camp and mine structures, exclusive of mill and refinery, including freight, teaming, cutting lumber	62,870
Plant and equipment	128,528
Surface exploration	2,152
Road construction	2,647
Clearing and burning; cutting saw logs, cordwood, and lagging	17,582
General teaming around plant	4,340
Sawmill operation (not included in cost of buildings)	2,379
General surface labor	8,629
Blacksmithing, steel sharpening, drill-repair labor, and nipping	9,589
Operation of power plant, compressors and hoists, including hauling firewood to boilers and electric power	19,319
Decking and surface tramming	6,502
Shaft sinking, direct labor only; 585 feet on 53° incline ...	25,204
Cutting shaft stations; direct labor only	2,465
Cutting loading pockets; direct labor only	2,935
Driving drifts and crosscuts, direct labor only; 4,308 feet..	25,430
Driving raises, direct labor only; 638 feet	5,396
Stoping	1,659
Starting winze	1,062
Miscellaneous	640
General underground labor	6,484
Unclassified underground labor, June and July, 1932	9,744
Sampling and assaying at mine	4,869
Office expense, salaries, and medical	15,490
Miscellaneous freight, unloading, and checking charges	608
Materials and supplies not included in plant appraisal	75,775
Subtotal	482,654
General accounts:	
Fire insurance	13,991
Workmens' compensation	5,753
Airplane travel (1931 to Aug. 31, 1932)	4,709
Hauling and freight not included in appraisal or itemized accounts	19,583
General travel expense, outside assaying, and miscellaneous accounts	3,828
Total general accounts	47,869
Total except mill and refinery	530,523

Mill and Refinery

The mill is a cyanide plant designed to treat 200 tons of ore per day, although the grinding section will handle only 125 tons per day with the present equipment. The grinding section is 45 by 48-2/3 feet and forms an end bay of the main mill building, which is 152½ by 67¼ feet; the total length is 197½ feet.

The superstructure is erected on concrete foundations carried to bedrock and is of steel-frame and trussed steel roof construction. The frame is sheathed with 2-ply lumber separated by hair felt and is covered with roll siding and roofing on the outside. The side walls are carried to a height of 17 feet above the foundations, and the ridge of the roof is 17 feet higher. The concrete floor slopes from each end and is 3 feet below the top of the wall foundations.

The refinery occupies a separate building 26 by 36 feet in plan and with hollow tile walls on concrete foundations. The side walls extend 10 feet above the top of the foundations, while the peak of the roof is 16½ feet above the foundations. The roof is carried on steel framework and is covered with corrugated iron.

The cost of the mill and refinery is summarized below. A considerable part of the equipment was transferred from other idle properties and is listed among the costs at its estimated present value. Costs include freight, teaming, and erection.

Mill and refinery costs

Mill building and foundation	$ 34,132
Refinery building and foundation	2,587
Total buildings	36,719
Mill equipment, foundations, and cost of installation	108,154
Refinery equipment and installation	714
Total equipment	108,868
Total mill and refinery	145,587

Summary of expenditures from date of discovery to date when mill started operation

Total exploration, diamond drilling, roads, camps, mine structures, camp and mine equipment, and underground development	$530,523
Mill and refinery	145,587
Grand total	676,110

Property No. 3.- Property No. 3 is 120 miles from railhead, and in 1928 and 1929 was partially developed to a depth of 268 feet. Expenditures are summarized as follows:

Summary of expenditures, property No. 3

Road and trail building	$ 2,108
Trenching and test pitting, and general exploration	5,027
Camp buildings	10,133
Housing of mining plant	2,627
Cost of materials, tools, and supplies	19,621
Cost of camp and mine equipment	36,276
Diamond drilling, supervision, and incidentals (2,000 ft.)	10,525
Shaft (268 feet deep) and two shaft stations	27,168
Drifting and crosscutting, 1,786 feet	37,667
Organization of company, secretary-treasurer, etc.	17,350
Engineering direction	6,435
	174,937
Credit $10,474 from shipment of high-grade ore	10,474
Net cost	164,463

Property No. 4.- The work at property No. 4, which is near a town and railroad, consisted of erection of buildings for housing the plant; installation of a substation, electrically driven hoist and compressor, etc.; and sinking a vertical shaft to a depth of 2,489 feet in which stations were cut at 250-foot intervals.

The cost of this work is summarized as follows:

Expenditures at property No. 4

Mine road and clearing site	$ 2,297
Buildings	5,854
Surface plant and equipment	50,810
Underground equipment	7,267
Total roads, buildings, and equipment	[1] 66,228
Shaft sinking, 2,489 feet	176,545
Total	242,773

[1] Does not include drill steel, sinking buckets, hoisting buckets, etc., which are included in the sinking cost.

Property No. 5.- Property No. 5 is remote from rail transportation. The mine structures included 19 buildings, two wooden headframes, a water tank, and a small ore trestle. The plant equipment included two wood-fired boilers, a steam driven hoist and compressor, blacksmith equipment and steel sharpener, sawmill, surface tracks and pipe lines, electric light plant, and assay equipment. The expenditures for exploration and development covered surface trenching and diamond drilling, the sinking of 556 feet of shaft, and 2,579 feet of drifting and crosscutting. These expenditures are summarized as follows:

Summary of expenditures, property No. 5

Exploration, trenching, test pitting, and diamond drilling ..	$ 91,827
Camp and plant structures	12,144
Camp and plant equipment	22,909
Mine equipment, rock drills and accessories, drill steel, cars, pumps, cage, etc.	3,381
Total exploration, camp and plant	130,261
Shaft sinking, 556 feet	37,723
Drifts and crosscuts (2,579 feet)	50,039
Cutting shaft stations (76 feet)	1,146
Total sinking, drifting, crosscutting, and stations	88,908
Equipment and supplies on hand and not charged into above accounts	25,530
Total expenditure	244,699

A milling plant has been installed since the work covered in the foregoing summary was completed, and the mine is now on a production basis.

Property No. 6.- Property No. 6 is 2½ miles from the railroad. Twenty-two buildings, two wooden headframes, and a water tank comprise the camp and plant structures. Plant and equipment include two electric hoists and two compressors, blacksmith equipment and a steel sharpener, pipe lines, surface pumps and motors, transformers and power line, rock drills and accessories, drill steel, underground pumps and motors, mine cars, sinking buckets and cages. The costs are summarized below:

Summary of expenditures, property No. 6

Camp buildings	$ 9,227
Plant buildings	23,150
Camp equipment	2,466
Plant equipment	56,668
Mine equipment	10,636
Total buildings and equipment	102,147
Surface trenching	336
Surface diamond drilling, 5,969 feet	22,443
Underground diamond drilling, 6,171 feet	27,105
Shaft sinking, 475.1 feet (shaft 14 feet 9 inches by 6 feet 8 inches)	31,229
Shaft stations, 38.3 feet	1,306
Drifts and crosscuts, 6,956 feet	117,645
Raising, 84.9 feet	1,603
Mine maintenance	4,440
Closing shaft	320
Total operating accounts	206,427
Total expenditure	308,574

CONCLUSION

The foregoing examples serve to indicate in a general way the costs of transportation, exploration, and plant equipment and the unit costs of underground development under the conditions peculiar to northern Ontario and Quebec, and bring out the point made in an earlier section of the paper that unit costs for underground development are much higher in a purely exploratory and development operation than in a producing mine.

Although only a few examples have been given, and although conditions differ at individual properties so that no estimate can be made of the expenditure required to prove a given prospect, the figures do indicate that in embarking upon the development of a prospect in this region, one should be prepared to expend at least $250,000 to $300,000 in order to determine whether the property will justify additional expenditure for a mill. It may require the expenditure of only a fraction of this amount in some instances to reach the conclusion that the property will not make a producer. On the other hand, this amount or much more may be required to prove that there is or is not a mine. Assuming that this amount, or more, is expended in discovering sufficient ore to warrant the erection of a mill, it is safe to anticipate that as much again will have to be spent before returns begin to come in from production.

In a gold mill there is considerable absorption of gold in the circuit for for the first two or three months. Capital requirements should be anticipated to take care of mine and mill operation during this period before income is appreciable.